Increasing productivity with smartphone digital imagery wound measurements and analysis

Objective: The primary aim was to determine the productivity increase using digital imagery for better documentation and analysis. A case series was done in a specialised care centre with patients managed with advanced dressings and using state-of-the-art smartphone technology for documentation to save costs and time.
Method: Wounds were cleansed and debrided before using the application to photograph, document, measure and analyse the wounds. The smartphone app was oriented parallel to the plane of the wound, where possible, to obtain accurate measurements.
A longitudinal study report was generated for each wound and showed the progress of the wound healing until the wound was closed.
Results: A sample size of 60 patients consisting of wounds from different locations, and a total of 203 measurements and analyses were conducted over a period of seven months. The wound monitoring app proved to be effective for wound monitoring and required less than two hours' training. A report summary of wounds recorded could also be generated automatically through the dashboard. All 60 patients' cases were automatically recorded, measured and presented into reports for use in clinical analysis. There was a significant time savings (27 hours per day for a specialised care centre with 10 nurses) increase over manual wound documentation and measuring methods.
Conclusion: The app provided a non-contact, easy to use, reliable and accurate smart wound management solution for clinicians and physicians to track wound healing in patients. The app could also be used by patients and caregivers for home monitoring of their wounds.
Declaration of interest: The author has no conflicts of interest.

cost • digital imagery • documentation • productivity • smartphone • time

With the digitalisation drive in Malaysia, the Government is encouraging the use of information technology to improve health-care by reducing costs and improving outcomes. In Malaysia, there is an ever-growing ageing patient population with chronic diseases such as wounds. Diabetes is on the rise, with 17.5% of the population having this debilitating disease.[1] In addition, 25% of these patients develop chronic wound complications. Increased monitoring to assist in identifying complications, customising local wound care treatments and adherence is required. There are many challenges in wound care, including: the lack of standardisation of consolidated wound data, such as a central wound documentation repository where clinicians can readily access well-presented patient wound records; and the high costs of treating wound complications resulting from lack of proper monitoring and fragmented efforts (Fig 1) .

The wound care unit in Hospital Kuala Lumpur (HKL) recognised the need for efficient monitoring of patients' wounds and was approached by the NDKare smart wound management solution development team to evaluate the use of such an application in a wound care centre setting. This application is a smartphone-based point-of-care system that will enable collaboration between medical disciplines, which aims to improve health outcomes, reduce costs and enhance patient experience (Fig 2).[2] A study has reported that it is an intuitive, secure, collaborative, cost-effective and stable wound care management system.[3] It requires a mobile smartphone, installed with the app, with an internet or 4G connection and is available on Android and iOS platform. In addition, it has an effective longitudinal wound report that meets legal and regulatory requirements and thae dashboard that allows clinicians to automatically generate longitudinal wound reports. The smartphone app is a commercially available product.[4]

A two year study (2015–2017), by the Home Nursing Foundation, Singapore, had more than four months' of quantitative data with a wide patient profile showing the reliability and the validity of using this application in patients with wounds.[3].

Aim

The aim of this study was to determine the productivity increase using digital imagery for better documentation and analysis.

Material and methods

The clinical evaluation of the digital application was done at the Wound Care Unit, Hospital Kuala Lumpur (HKL)

Harikrishna K.R. Nair,[1] MD FRCPI FCWCS FMSWCP
Corresponding author email: hulk25@hotmail.com
1 Department of Internal Medicine, SCACC Kuala Lumpur Hospital, Jalan Pahang, 50586 Kuala Lumpur, Malaysia.

Fig 1. Identified challenges in clinical practice

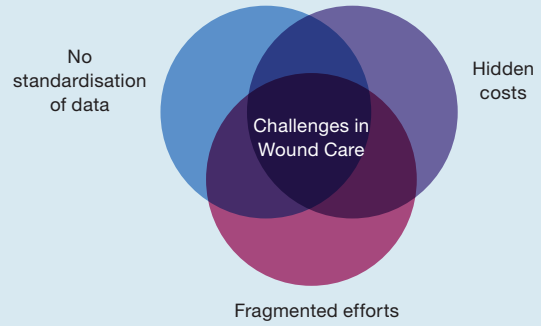
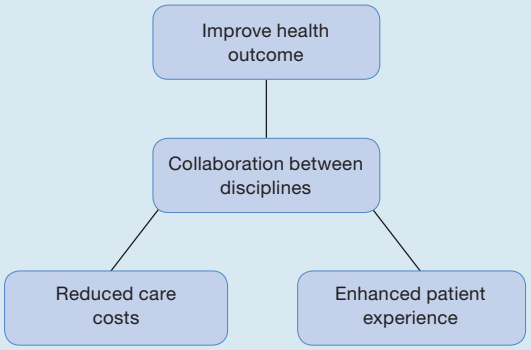


Fig 2. Potential benefits of smart wound management solution



from January to July 2018 (seven months). Patients were chosen from the population of HKL's wound care unit. Patients that satisfied the inclusion criteria were selected randomly to remove bias from the study. A wound care nurse was assigned to a specified patient, and the same nurse took all the measurements throughout the study to avoid any inconsistencies in use and interpretation of the app. There were three nurses involved in the study and patients fitting inclusion criteria and taken care of by any of the three nurses were enrolled

Training for using the smartphone app was conducted by the company's development team for nurses at the Wound Care Unit at HKL. The nurses were trained to take a single photo of the wound and a video of the wound with the smartphone camera at a fixed distance and at different angles. Proficiency was determined by ensuring the nurses were able to use the app to measure and document the wound effectively. The nurses were able to learn how to use it within two hours.

The basic procedure was that the wound care nurse removed the bandage and cleaned the wound thoroughly, including debridement, before the app was used.

Measurement and documentation

The following protocol was followed:

- Ensure that the patient is comfortably positioned in the anatomically correct position
- Position the marker in the same plane of the wound
- Position the camera apparatus at a standard distance of approximately 5cm from the wound
- Take the photo at a consistent perpendicular angle of the wound
- Take one video of the wound at fixed distance and at different angles

The measurements and photos were stored securely and encrypted on a server maintained and protected by the service provider. Measurements are recorded in the database. Area measurements based on actual area (based on perimeter for the wound) and the area based on length x width were compared.

Inclusion criteria

- External wounds
- Patients with wound length <20cm and width <20cm
- Age (to follow the patient distribution of HKL)
- Gender (to follow the patient distribution of HKL)
- Race (to follow the patient distribution of HKL)
- Number of wounds on the patient (no limit).

Exclusion criteria

- Non-blanchable erythema of intact skin
- Wounds with significant curvature where the marker cannot be placed on the same plane as the wound.

Non-blanchable erythemas were excluded as they appear only as redness on the skin e.g. category 1 pressure ulcers.

The outcome measure was to examine if the time and cost savings in the measurement and documentation of wound could be obtained by using the app.

Results

We recruited 60 patients with a variety of wounds, including DFUs and PUs, from different locations and a total of 203 measurements and analyses were conducted over a period of seven months.
Here we present a selection of cases.

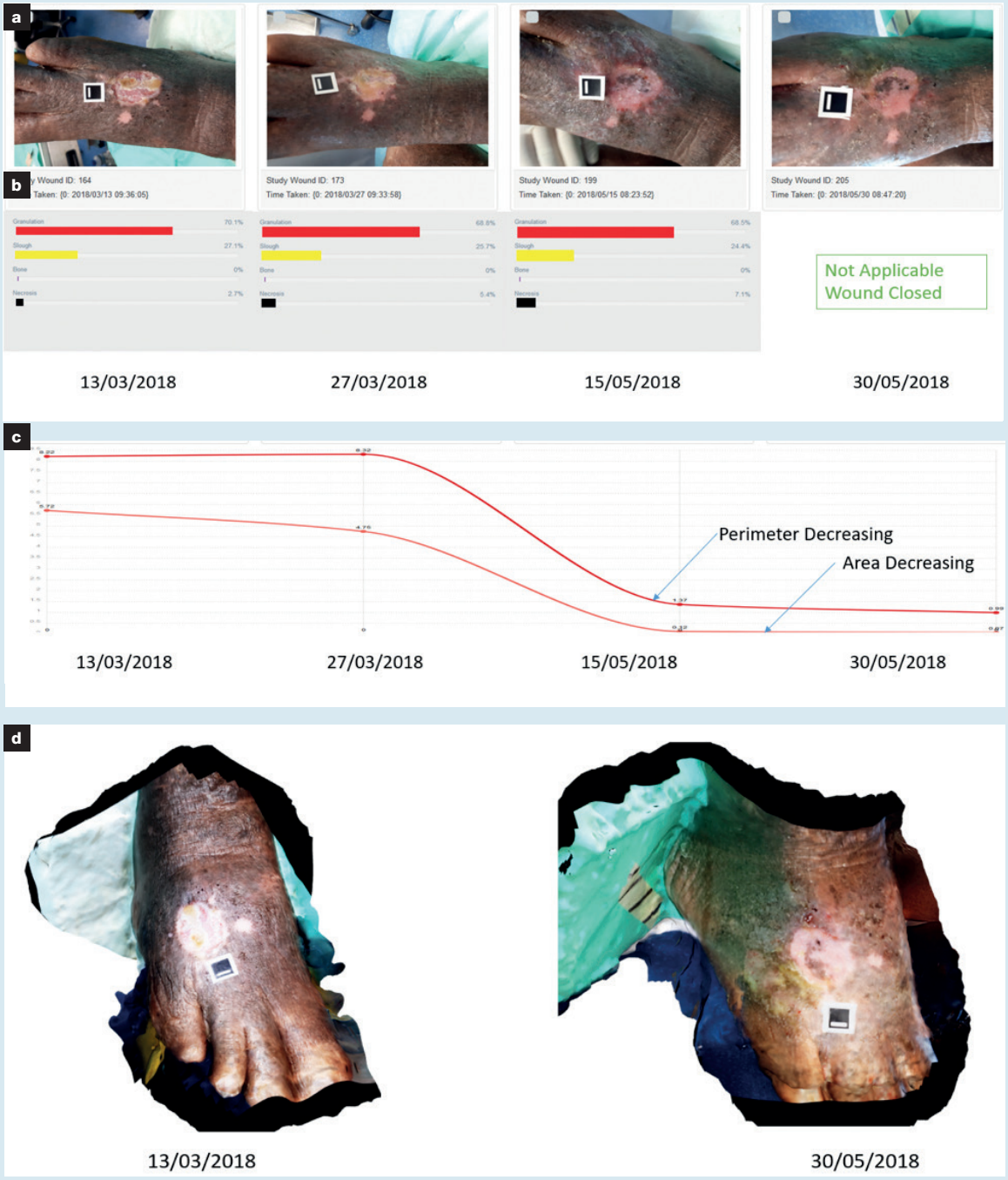
Case 1: diabetic foot ulcer (right foot)

A 92-year-old male with a DFU of the right foot of approximately five months' duration. Comorbidities included chronic venous ulcer and stasis eczema. The wound was treated with stimulen gel (South West Technologies) with PolyMem Pink (PolyMem). Using the app, actual wound area decreased from an initial size of 5.7cm^2 to closure of the wound. The area calculated based on length and width measurements decreased from 7.9cm^2 to closure of the wound (Fig 3).

Case 2: diabetic foot ulcer (left foot)

A 71-year-old male with a DFU of the left foot. The patient had diabetes. The wound was treated with stimulen gel. Using the app, the actual wound area decreased from 7.8cm^2 to closure recorded over approximately 2 months. The area calculated on length and width measurements decreased from 10.8cm^2 to closure (Fig 4).

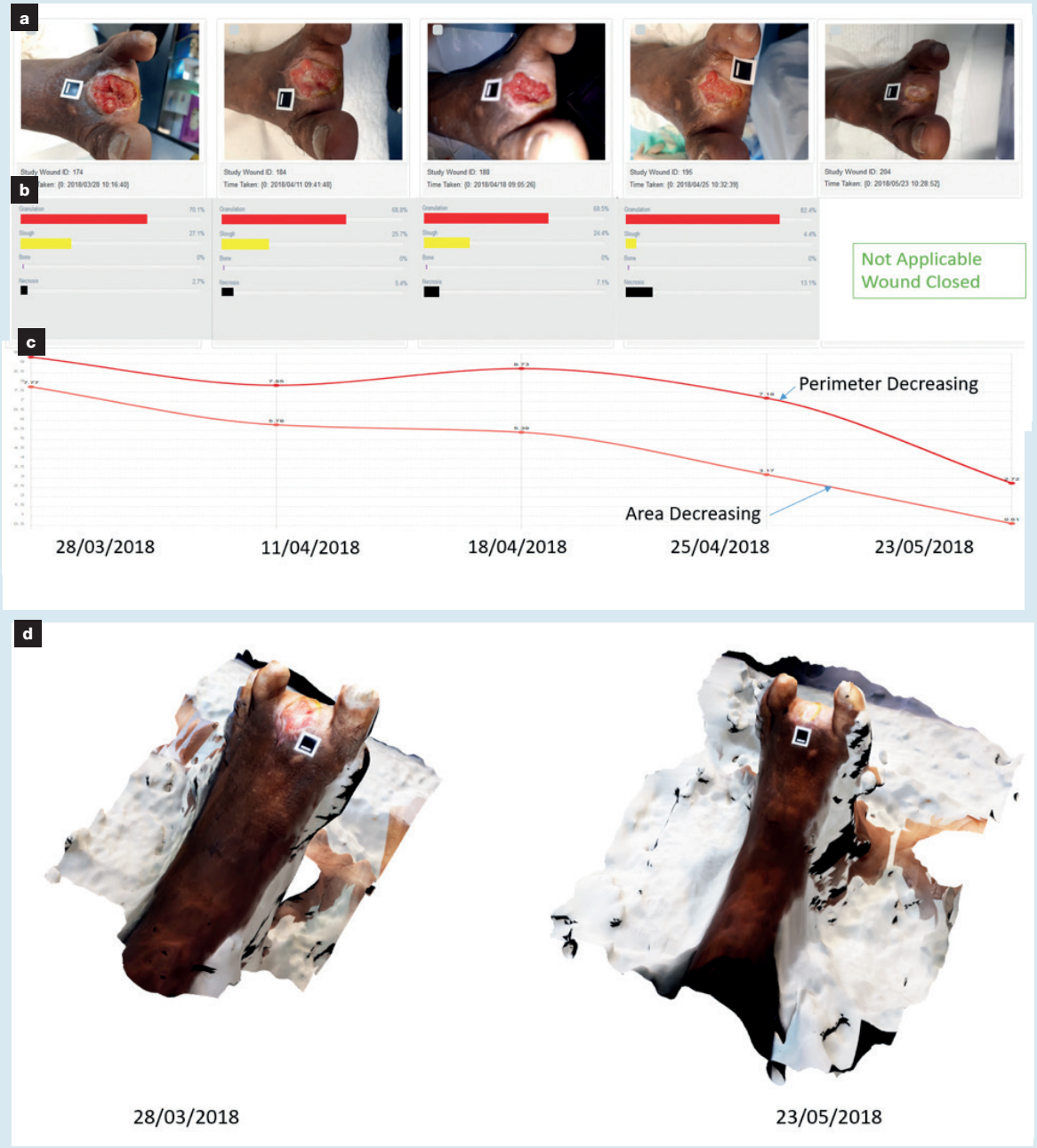
Fig 3. Case 1, diabetic foot ulcer, right foot . Progression of wound healing from initial presentation (13 March 2018) to complete closure (30 May 2018) (**a**). Automatic measurements of granulation, slough, bone and necrosis (**b**). A line graph showing perimeter and area measurements over same timepoints (**c**). Wound at initial presentation and at closure using the apps digital imagery (**d**)



Case 3

A 41-year-old female with a wound on the right thigh. Comorbidities included diabetes and psoriasis anaemia. The wound was treated with MediHoney (Derma Sciences), L-Mesitran Tulle (Mesitran Netherlands), BETAplast N (Mundipharma) and barrier cream. Using the app, the actual area decreased from 99.8cm^2 to closure of the wound. The area calculated based on length and width measurements decreased from 152cm^2 to closure of the wound.

Fig 4. Case 2, a diabetic foot ulcer (left foot). Progression of wound healing from initial presentation (28 March 2018) to complete closure (23 May 2018) (**a**). Automatic measurements of granulation, slough, bone and necrosis (**b**). A line graph showing perimeter and area measurements over same timepoints (**c**). Wound at initial presentation and at closure using the apps digital imagery (**d**)



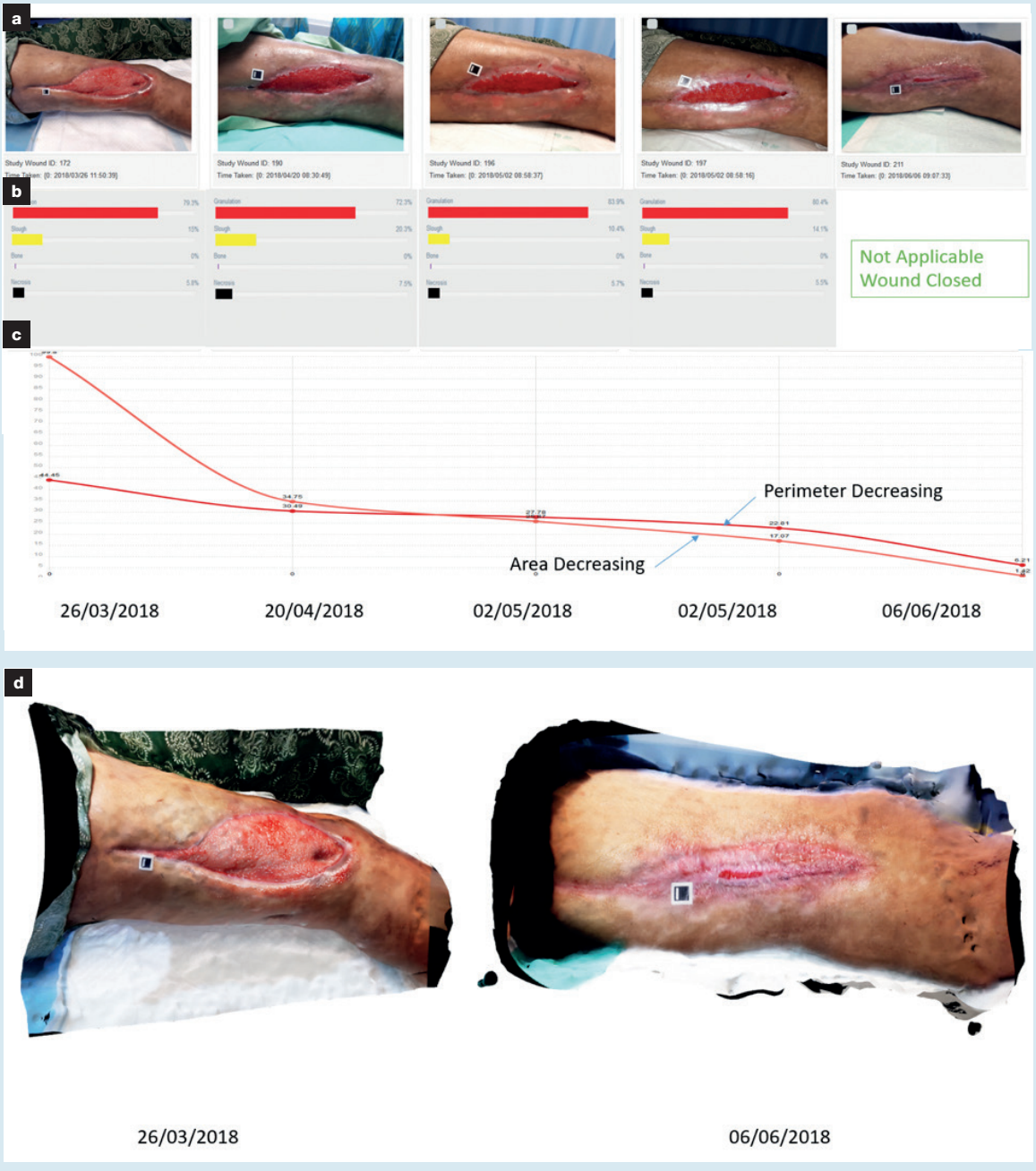
Case 4: diabetic foot ulcer

A 48-year-old male with DFU. The patient was diabetic. The wound was treated with medihoney, BETAplast N, barrier cream, Natrox (Inotec) and stimulant lotion. Using the app, the actual areas of the wound decreased .from an initial 20.3cm^2 to closure of the wound. The area calculated based on length and width measurements decreased from 50.7cm^2 to closure of the wound.

Estimated productivity increase and cost savings

Clinician compensation was based on the average pay of a nurse in Malaysia, estimated at RM3000 Malaysia Ringgit (approximately US$730, £570) (Table 1). The same computation can be adapted to different scenarios and for different countries currencies. This also assumed that each nurse would receive a bonus of one month's pay at the end of the year. There was also no overtime

Fig 5. Case 3, a 41-year-old female with a right thigh wound. Progression of wound healing from initial presentation (26 March 2018) to complete closure (6 June 2018) (**a**). Automatic measurements of granulation, slough, bone and necrosis (**b**). A line graph showing perimeter and area measurements over same timepoints (**c**). Wound at initial presentation and at closure using the apps digital imagery (**d**)



work required of the nurses and the calculation deducted the holidays in a year to compute the average cost per hour, RM20.48 (Table 2).

Full measurement (length, width, area, perimeter, depth and volume) and documentation of the patient's wound was estimated to take 30 minutes. Using the smartphone app, the time taken to measure the wound, was estimated to be at most five minutes. Giving a manpower cost saving per wound measurement of RM8.53 (Table 2)

At the specialised wound care unit at HKL, there are a total of 10 nurses and the number of patients visiting the centre averages 65 patients per day. Based on this the total cost savings per annum were estimated to be RM133,140.76 based on 20 working days per month 12 months a year (Table 2)

Fig 6. Case 4, diabetic foot. Progression of wound healing from initial presentation (13 March 2018) to complete closure (30 May 2018) (**a**). Automatic measurements of granulation, slough, bone and necrosis (**b**). A line graph showing perimeter and area measurements over same timepoints (**c**). Wound at initial presentation and at closure using the apps digital imagery (**d**)

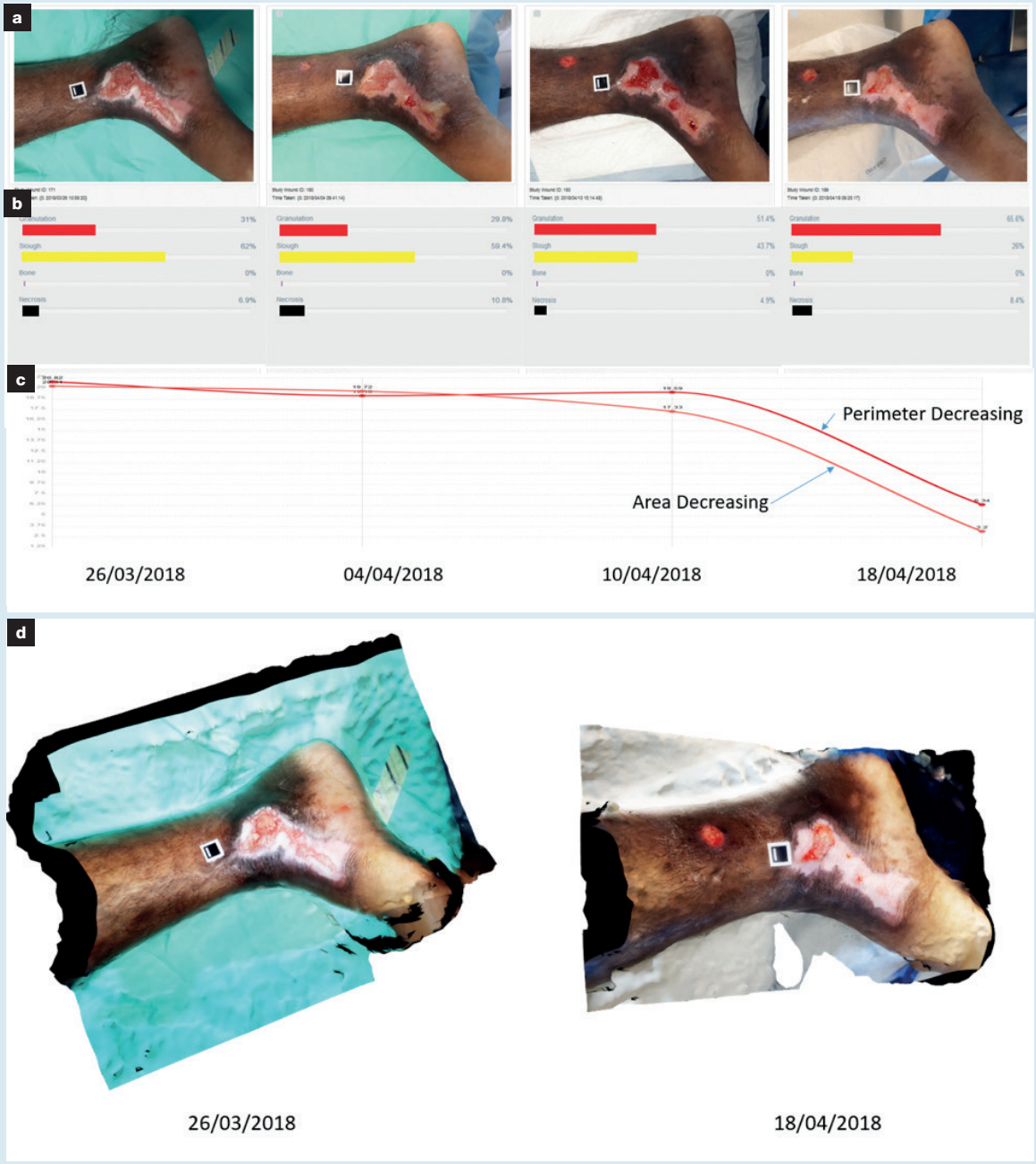


Table 1. Assumptions about clinicians' pay

Assumptions	
1	No over-time compensation
2	Average salary of RM3000 (in Malaysian ringgit)
3	Bonus of one month's pay in addition to monthly pay
4	Exclude compliance costs

Each nurse undertook the following processing starting with registering the patient, preparing the patient, assessing the patient, cleaning the wound, measuring/documenting the wound, treating and bandaging the wound.

The savings estimated only considers the time savings for nursing staff. There will be further savings for other office staff, such as registration receptionists and assistants that is not included in this calculation.

Due to the time savings, it was possible for the wound care unit to perform up to 325 wound measurements and documentations per day in the specialised care centre, as shown in Table 3.

Discussion

In the Wound Care Unit, Dept of Internal Medicine, the use of a manual ruler or wound tracing has been a well-established norm due to the low cost and ease of use. However, there are reliability and accuracy issues with this technique. Therefore, a pilot study was conducted with the smartphone application over a two-month period which showed the practicality and ease of use of this application in the overall management of the wounds.[4]

The smartphone application has proven to have validity in accuracy for length, width, area and perimeter. From the clinicians' perspective, there are time savings, productivity savings of 500%, ease of use, seamless trending of wound progress into the electronic medical record and, last but not least, better photographic clarity to facilitate multidisciplinary discussion.

Limitations

This study only assessed the use of the app to measure wounds; this was not compared with traditional methods for comparative analysis. Furthermore, the time taken for measurement was an estimation based on our experience rather than actual timing, although we believe these are consistent in our experience.

Conclusion

The non-invasive nature of this application also improved quality and consistency with, a reduction in errors in clinical wound-care documentation. Adoption of this solution would reduce costs and improve workflow. Applications such as this are beneficial in terms of better financial management, ability to track return on investment and variable costs, and as a collaborative mobile platform whereby there is remote accessibility and ease of collaboration between disciplines. JWC

Table 2. Total cost savings per annum for specialised wound care centre at Hospital Kuala Lumpur

Cost per hour				
Hours	**Week**	**Cost of a registered nurse (RM3000 x 13 months)**	**39,000**	**per annum**
42	52	1 nurse works 42 hour/week (52 weeks per year)	2184	hours/year
Days	**Hours/day**			
21	8	Subtract 21 days annual leave (8 hour per day)	168	hours/year
11	8	Subtract 11 days public holidays (8 hours per day)	88	hours/year
3	8	Buffer three days for family care leave, medical leave	24	hours/year
		Net work hours per nurse	1904	hours/year
		Cost per hour	**RM20.48**	**per hour**
Time and cost savings per patient				
Mins	**Manpower cost saving app versus manual measure**			
30	Manpower cost for manual wound measurement			RM10.24
5	Manpower cost for wound measurement using app			RM1.71
	Manpower cost savings per wound measurement using app versus manual			RM8.53
Patients per day for specialised care centre at Hospital Kuala Lumpur				
65	Manpower cost for 65 patients per day (assuming one wound per patient)			RM554.75
Working days				
20	Cost savings per month (20 working days)			RM11,095.06
Cost savings/year (20 working days/month x 12 months)				**RM133,140.76**

Table 3. Productivity increase in time

Productivity	**Per day**		
	No. of patients	**No. of nurses**	**Time needed (min)**
Status quo	65	10	1950
Wound app	65	10	325
Total time difference (δ)			1625
% productivity increase			500% #3
Wound measurement unit can take up to 325 patients